KEITHLEY

Model 868 and 869 Digital Thermometers

Instruction Manual

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WARRANTY

We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace, at our option, any instrument thereof which, within a year from date of shipment, proves defective upon examination. We will pay local domestic surface freight costs. (NOTE: This warranty does not cover battery replacement or damage due to battery leakage.)

SERVICE POLICY

For service on your instrument, contact your local Keithley representative who will be able to give you immediate assistance in most cases. Complete repair and calibration facilities are maintained in the United States, West Germany, Great Britain, France, the Netherlands, Switzerland, and Austria. Information concerning the application, operation or service of your instrument may be directed to the applications engineer at any of the above locations.

STATEMENT OF CALIBRATION

This instrument has been inspected and tested in accordance with specifications published by Keithley Instruments, Inc. The accuracy and calibration of this instrument are traceable to the National Bureau of Standards through equipment which is calibrated at planned intervals by comparison to certified standards maintained in the Laboratories of Keithley Instruments, Inc.

SPECIFICATIONS

MODEL 868 SPECIFICATIONS

TEMPERATURE SENSOR TYPE: 3 wire or 4 wire 100 Ohm Platinum RTD (alpha = 0.00385).

RANGE	TEMPERATURE SPAN	RESOLUTION	4 WIRE ACCURACY* (65° to 82°F; 1 year)
200°F	-150.0° to 199.9°	0.1°	±0.4°F
	-199.9° to -150.1°	0.1°	±1.0°F
1100°F	- 360° to 1100°	1°	± 2°F

***ACCURACY:** Includes DIN 43 760 conformity, repeatability, temperature coefficient (65° to 82°F), time stability (1 year) and errors with up to 50 ohms of lead resistance (each lead). Excludes probe errors; however probe errors around 32°F may be compensated by an internal adjustment.

REPEATABILITY: 0.2°F typical for 1 week at constant ambient temperature.

TEMPERATURE COEFFICIENT: 65° to 82°F; included in accuracy specification. From 14° to 65° and 82° to 122°F: less than ±0.015°F/°F.

MAXIMUM LEAD RESISTANCE (each lead): 4 Wire; 50 ohms
3 Wire; 10 ohms

SENSOR CURRENT: 500μA maximum.

MODEL 869 SPECIFICATIONS

TEMPERATURE SENSOR TYPE: 3 wire or 4 wire 100 Ohm Platinum RTD (alpha = 0.00385).

RANGE	TEMPERATURE SPAN	RESOLUTION	4 WIRE ACCURACY* (18° to 28°C; 1 year)
200°C	-150.0° to 199.9°	0.1°	±0.3°C
	-199.9° to -150.0°	0.1°	±1.5°C
630°C	-220° to 630°	1°	±1°C

***ACCURACY:** Includes DIN 43 760 conformity, repeatability, temperature coefficient (18° to 28°C), time stability (1 year) and errors with up to 50 ohms of lead resistance (each lead). Excludes probe errors; however probe errors around 0°C may be compensated by an internal adjustment.

REPEATABILITY: 0.1°C typical for 1 week at constant ambient temperature.

TEMPERATURE COEFFICIENT: 18° to 28°C; included in accuracy specification. From -10° to 18° and 28° to 50°C: less than ±0.015°C/°C.

MAXIMUM LEAD RESISTANCE (each lead): 4 Wire; 50 ohms
3 Wire; 10 ohms

SENSOR CURRENT: 500μA maximum.

MODEL 868 and 869 GENERAL SPECIFICATIONS (unless specified):

DISPLAY: 3½-digit LCD, 13mm (0.5") height. Polarity and decimal point indication.

CONVERSION RATE: 1.5 readings per second.

OVERRANGE AND OPEN SENSOR INDICATION: 3 least significant digits blanked.

MAXIMUM COMMON MODE VOLTAGE: 42V peak to earth.
COMMON MODE REJECTION: Less than 0.001°/volt at DC, 50Hz and 60Hz. (100Ω unbalance, LO driven)
ENVIRONMENTAL LIMITS FOR OPERATING: -10° to 50°C (14° to 122°F), less than 80% relative humidity up to 35°C (95°F); linearly derate 3% R.H./°C from 35° to 50°C (1.5% R.H./°F from 95° to 122°F).
ENVIRONMENTAL LIMITS FOR STORAGE: -35° to 60°C (−30° to 140°F), less than 90% relative humidity up to 35°C (95°F); linearly derate 3% R.H./°C from 35° to 60°C (1.5%/°F from 95° to 140°F).
RTD LINEARIZATION: Ratiometric dual-slope A/D with continuous linearization.
INPUT CONNECTION: 4 pin miniature instrumentation connector.
POWER: 9V alkaline or carbon-zinc (NEDA 1604) battery.
BATTERY LIFE, CONTINUOUS: 500 hours typical with alkaline battery; 300 hours typical with carbon-zinc battery.
BATTERY INDICATOR: Display indicates "LO BAT" when less than 10% of life remains.
DIMENSIONS, WEIGHT: 160mm long × 69mm wide × 31mm thick (6.3" × 2.7" × 1.2"). Net weight 210gm (7.5 oz.)
CONSTRUCTION: Heavy duty ABS plastic housing.
ACCESSORIES SUPPLIED: Battery, instruction manual and mating input connector.

Specifications subject to change without notice.

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GENERAL INFORMATION

The Keithley Models 868 and 869 are handheld digital thermometers designed to use 100Ω platinum RTD temperature sensors for high accuracy and long term temperature stability. The Model 868 has two switch-selectable ranges: from -199.9°F to +199.9°F with 0.1°F resolution, and between -360°F and +1100°F with 1°F resolution. The Model 869 measures between -199.9°C and +199.9°C with 0.1°C resolution, or between -220°C and +630°C with 1°C resolution. Both instruments are designed for use with probes conforming to the DIN 43 760 standard.

Model 868 and 869 features include:

1. Platinum RTD Based Temperature Measurements. A chief advantage of the platinum RTD (resistance temperature detector) sensor used by the unit is platinum's predictable resistance change with temperature, resulting in high accuracy.
2. Easily selected 3- or 4-Wire Measurements. The unit may be used with either 3-wire or 4-wire temperature probes. An internal switch provides a means of easy 3- or 4-wire selection (the unit is set for 4-wire operation at the factory).
3. Rugged Case. The instrument's case is made of high impact ABS plastic.
4. Long Battery Life. Because of low power consumption, an alkaline battery will typically last for 500 hours of continuous operation.

MANUAL ADDENDA

Information presented in this manual was believed to be accurate at the time of printing. Any changes in the instrument, which occur after this manual is printed, will be covered separately in an addendum packed with the instrument. Be sure to note these changes before attempting to operate or service the instrument.

OPTIONAL ACCCESSORIES

Available accessories, including recommended temperature probes, are listed below. Contact your Keithley representative or the factory for information on purchasing accessories.

Model 8660 Tilt Stand/Belt Clip provides a convenient method of elevating the instrument to a convenient viewing height. The Model 8660 also includes a belt clip.

Model 8668 Soft Carrying Case provides protection for the Model 868 or 869 during transportation or storage.

Model 8691 Accessory Kit includes a male 4-wire connector and quick disconnect 3-wire adapters. The kit also includes a female 4-wire connector prewired to a 4-wire coiled extension cable.

Model 8693 General Purpose Immersion Probe is a 4-wire 100Ω platinum RTD probe designed for immersion in liquids as well as other general purpose applications. The Model 8693 has a basic tolerance of ±0.3°C at 0°C. The measurement range of the Model 8693 is -220°C to +630°C.

Model 8695 Surface Probe is a 4-wire 100Ω platinum RTD probe designed to measure flat surfaces of solids in the range of -50°C to +260°C. The Model 8695 has a basic tolerance of ±0.3°C at 0°C.

Model 8696 Air/Gas Probe is a 4-wire 100Ω platinum RTD probe with an exposed sensor within a protective shroud to measure ambient temperature. The Model 8696 measures between -50°C and +260°C. The basic tolerance of the Model 8696 is ±0.3°C at 0°C.

PREPARATION FOR USE

Carefully unpack the instrument from its shipping carton and inspect for any obvious signs of physical damage. Report any damage to the shipping agent at once. The following items are included with every shipment:

1. Digital Thermometer
2. Instruction Manual
3. 9V battery (NEDA 1604).
4. 4-wire miniature instrumentation connector (mates with probe connector on the instrument).

NOTE

As shipped, the instrument is configured for 4-wire probes. See the operation section for selection of 3-wire operation.

BATTERY INSTALLATION/REPLACEMENT

A 9V battery is supplied with the unit. To install or replace the battery, proceed as follows:

WARNING

Turn off the power and disconnect the temperature probe before removing the back cover to install or replace the battery. Replace the back cover before resuming use of the instrument.

1. Place the unit face down on a cloth-covered flat surface.
2. Remove the screws in the back cover; now remove the back cover by carefully separating the two halves at the top of the instrument.
3. Place the 9V battery (NEDA 1604) in the battery compartment as indicated in Figure 3. Be sure to observe proper polarity.
4. Make sure the shield is in place; then reinstall the rear cover on the instrument. Make sure the two case halves line up properly; now secure the rear cover with the screws that were removed earlier.

SAFETY SYMBOLS AND TERMS

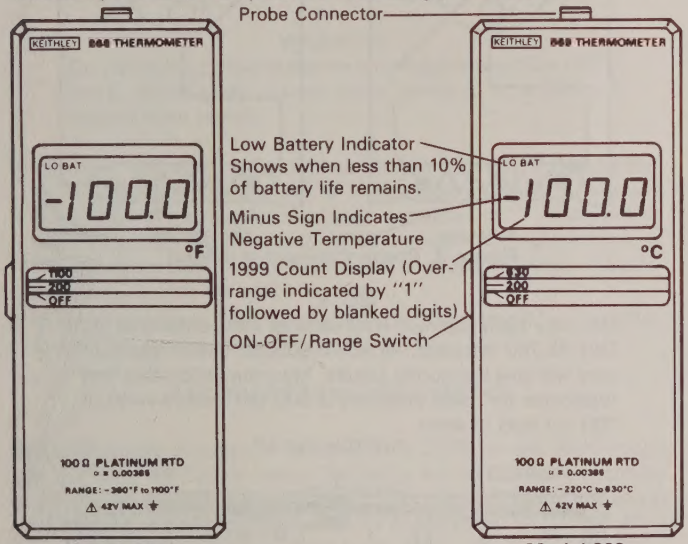
The symbol ⚠ on the instrument denotes that the user should refer to the operating instructions.

The **WARNING** used in this manual explains dangers that could result in personal injury or death.

The **CAUTION** used in this manual explains hazards that could damage the instrument.

OPERATION

Figure 1 shows the general control layout, including display nomenclature, for your digital thermometer. The following paragraphs contain information on probe connection, 3- and 4-wire selection, range selection, and basic temperature measuring procedures.



Model 868 **Model 869**

Figure 1. Control and Display Nomenclature

1. Connect the temperature probe to the probe connector on the top of the instrument. Use a recommended probe as described in the accessories section; alternately, a probe may be constructed using the information in Figure 2.
2. Make sure the instrument is selected for 3-wire or 4-wire operation according to probe type in use. The unit is set for 4-wire operation at the factory, but the mode of operation may be changed as follows:
   A. Remove the rear cover as described in the servicing information section of this manual.
   B. Place the 3-wire/4-wire switch (see Figure 3) in the desired position as indicated on the shield.

C. Reinstall the rear cover and tighten the retaining screws.

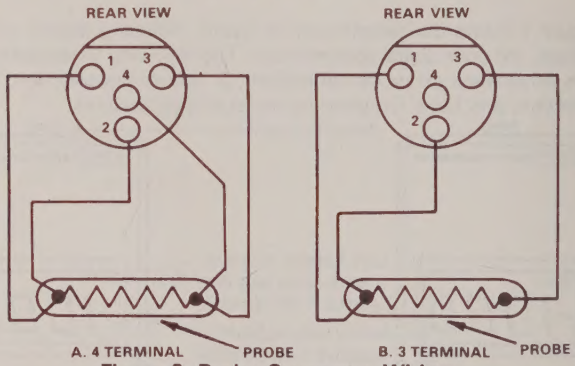


Figure 2. Probe Connector Wiring

NOTE

Use only 100Ω platinum RTD sensors that conform to the DIN 43 760 standard (alpha = 0.00385). Other type sensors will give inaccurate results. Maximum allowable lead resistance for rated accuracy is 50Ω per lead (4-wire) or 10Ω per lead (3-wire).

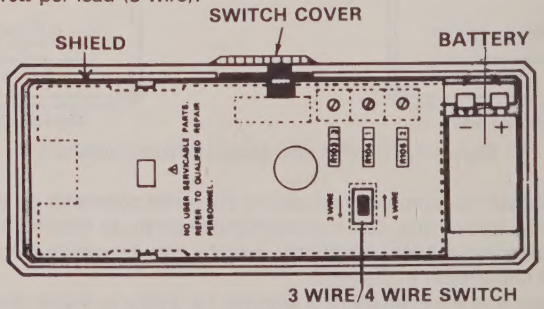


Figure 3. 3-Wire/4-Wire Switch Location

NOTE

For best accuracy, it is recommended that the instrument be used in the 4-wire configuration with a suitable 4-wire probe. If 3-wire probes are used with the instrument in the 4-wire mode, noisy readings will result (the displayed reading will jump around). Unlike 4-wire readings, 3-wire

reading accuracy is affected by changes in lead resistance as well as to differences in lead resistance.

3. Place the temperature range switch in the desired position. Use the lower range, when possible, for best resolution and accuracy. Power is automatically turned on when the range is selected.
4. Place the probe tip on or in the material to be measured.

WARNING

Do not subject the probe to a voltage more than 30V RMS, 42.4V peak above earth ground, or a shock hazard may result.

5. Take the reading from the display. The reading is in °F (Model 868) or °C (Model 869). A leading minus sign indicates a negative temperature reading. An overrange condition (a "1" followed by blanked digits) may indicate the need to switch to a higher range, or show that the temperature is outside the measuring range of the instrument, or that the probe is open.
6. When the measurement is complete, place the on-off/range switch in the OFF position to conserve the battery.

ACCURACY CONSIDERATIONS

Model 868 basic accuracy is specified as ±0.4°F for the 200°F range and ±2°F for the 1100°F range. Similarily, Model 869 basic accuracy is ±0.3°C on the 200°C range and ±1°C on the 630°C range. Keep in mind that these accuracy figures are for 4-wire probe operation with a lead resistance of less than 50Ω (each lead). Thus, 4-wire probes should be used, whenever possible, to maintain the highest accuracy.

Accurate readings can also be made with the instrument in the 3-wire mode with a suitable 3-wire probe. For best accuracy, however, lead resistance should be no more than 10Ω per lead. Also, readings made in the 3-wire mode are sensitive to variations caused by changes in lead resistance as well as to differences in lead resistance. For example, a difference of only 38mΩ (0.038Ω) in lead resistance will cause a change of 0.1°C around 0°C. Four-wire readings are not affected by these lead resistance variations.

Accuracy figures do not include possible probe errors, which could affect overall measurement accuracy. Probe errors near 32°F for the Model 868, and near 0°C for the Model 869, can be minimized by recalibrating the instrument for use with a specific probe. For probe calibration procedures, refer to the calibration section of this manual.

The operating temperature of the instrument itself can affect accuracy. The accuracy figures given above are for an instrument operating in the range of 18°C to 28°C (65°F to 82°F). For operating environments between -10°C and 18°C (14°F and 65°F) and between 28°C and 50°C (82°F and 122°F), a temperature coefficient of less than $\pm 0.15°C/°C$ ($\pm 0.15°F/°F$) can be expected.

SERVICING INFORMATION

This section contains information on performance verification, calibration, theory of operation, and a troubleshooting guide. The PC board component layout, schematics, and parts list are also included at the end of this section.

WARNING

The information in this section is intended only for qualified service personnel. Before removing the back cover to service the instrument, disconnect the temperature probe.

PERFORMANCE VERIFICATION

Performance verification is performed by connecting known, precise resistors to the instrument in place of a temperature probe and checking to see that the displayed reading falls within a prescribed range. The following procedure should be performed at an ambient temperature between 18°C and 28°C (65°F and 82°F) at a relative humidity of less than 80%. If the instrument has been stored outside these limits, allow at least 24 hours for operating conditions to stabilize.

Required Equipment:

Precision decade resistance box, ±0.01% tolerance (Gen Rad Model 1433T or equivalent)

Female 4-wire instrumentation connector (supplied with instrument).

NOTE

The following procedure must be performed with the instrument in the 4-wire mode. See Figure 3 for the location of the 3-wire/4-wire switch which sets the appropriate mode. Access to the switch requires rear cover removal as described in the disassembly instructions.

Procedure:

1. Connect the precision resistance box to the instrumentation connector as shown in Figure 4. Plug the connector into the instrument.
2. Turn on the instrument and verify that the LO BAT indicator is not displayed; if it is, replace the battery before beginning the verification procedure.

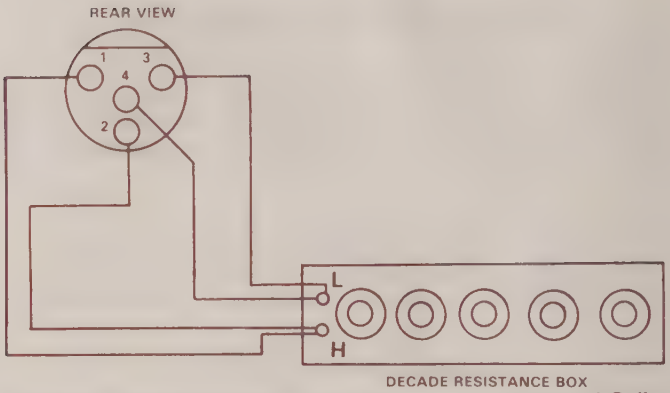


Figure 4. Connections for Performance Verification and Calibration

3. Refer to Table 1, which lists the verification procedure for both instruments covered by this manual. To verify instrument performance at each of the points, set the resistance box to the required value; with the instrument on the prescribed range, verify that the displayed reading falls within the necessary limits.
4. If the displayed reading is out of tolerance at any of the points, refer to the calibration section for the correct procedure to bring the instrument within tolerance.

NOTE

If the instrument is still under warranty (less than 12 months since the date of shipment), and it does not meet specifications after calibration, contact your Keithley representative or the factory to determine the correct course of action.

Table 1. Performance Verification Procedure

Model 868		
Range	**Resistance Value**	**Allowable Reading (65°F to 82°F)**
1100°F	11.29Ω	-362 to -358
200°F	71.00Ω	-100.4 to -99.6
200°F	93.03Ω	-0.4 to +0.4
200°F	114.68Ω	99.6 to 100.4
200°F	134.91Ω	194.6 to 195.4
1100°F	311.45Ω	1098 to 1102

Table 1. Performance Verification Procedure (Cont.)

Model 869		
Range	Resistance Value	Allowable Reading (18°C to 28°C)
630°C	10.41Ω	-221 to -219
200°C	60.25Ω	-100.3 to -99.7
200°C	100.00Ω	-0.3 to +0.3
200°C	138.50Ω	99.7 to 100.3
200°C	174.00Ω	194.7 to 195.3
630°C	313.59Ω	599 to 601

CALIBRATION

Calibration should be performed yearly or whenever the instrument is known to be out of specification. Calibration should be done at an ambient temperature of 23 ± 1°C at a relative humidity of less than 80%. Normal instrument calibration is performed by substituting precision resistors of known value for the temperature probe and adjusting calibration potentiometers for specified readings on the display. The instrument may also be calibrated to compensate for probe errors near 0°C (32°F). Both procedures are covered in this section.

Calibration Equipment:

Gen Rad precision decade resistor box, ±0.01% tolerance, (Model 1433T or equivalent).

Female 4-wire instrumentation connector (supplied with instrument).

The following items are necessary only for probe compensation:

Distilled ice water bath in Dewar flask or thermos.

Platinum RTD immersion probe (Model 8693 or equivalent).

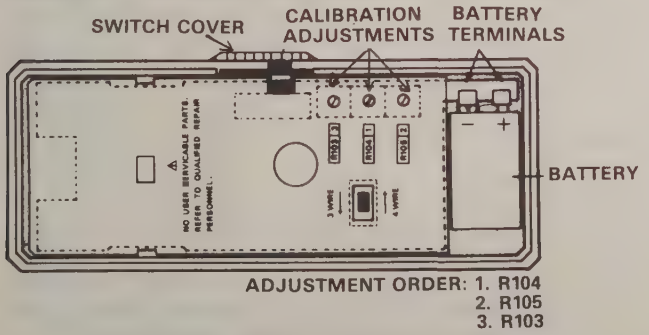


Figure 5. Calibration Adjustment Locations

GENERAL INSTRUMENT CALIBRATION

1. Connect the precision decade resistor box to the instrument as shown in Figure 4.
2. Remove the rear cover as described in the disassembly instructions. Note that it is not necessary to remove the PC board or shield to perform calibration.
3. Check to see that the 3-wire/4-wire switch is in the 4-wire position.
4. Turn on the instrument power and verify that the LO BAT indicator is not displayed. If it is, replace the battery before beginning the calibration procedure.
5. Refer to Table 2. Calibration procedures are outlined here. Perform each step in the procedure in the order shown by setting the decade box to the precise value listed and then adjusting the associated calibration potentiometer for the required reading on the display. Potentiometer locations are shown in Figure 5 and are marked on the shield.
6. If probe compensation is required, proceed to the next paragraph; otherwise dismantle the test fixture, set the 3-WIRE/4-WIRE switch to the correct position and replace the back cover.

Table 2. Calibration Procedure

Model 868				
Step	Adjustment Potentiometer	Range	Calibration Resistor Value	Desired Reading
1	R104	200°F	93.03Ω	00.0
2	R105	200°F	134.91Ω	195.0
3	R103	1100°F	311.45Ω	1100

Model 869				
Step	Adjustment Potentiometer	Range	Calibration Resistor Value	Desired Reading
1	R104	200°C	100.00Ω	00.0
2	R105	200°C	174.00Ω	195.0
3	R103	630°C	313.59Ω	600

PROBE COMPENSATION CALIBRATION

The procedure outlined in the last paragraph provides accurate absolute instrument calibration, but it cannot compensate for probe inac-

curacy. Probe errors near 0°C (32°F) can be minimized by using the following procedure.

1. Make up an ice water bath by firmly packing a Dewar flask or thermos with pea-size ice cubes made of distilled water and then filling the container with distilled water. Replace melted ice with new ice while removing excess water during the calibration procedure.
2. Connect the probe to be compensated to the instrument.
3. Drill a hole in the flask or thermos cap just large enough to accomodate the probe. Place the cap on the bath container and pass the probe through the hole until the probe tip rests at the center of the ice water bath.
4. Allow 20 minutes for the test fixture temperature to stabilize. With the Model 868 on the 200°F range, adjust R104 for a reading of 32.0 on the display. For the Model 869, R104 should be adjusted for a reading of 00.0 with the instrument on the 200°C range.

NOTE

Using this method of probe calibration will uncalibrate the instrument slightly when used with other probes.

DISASSEMBLY INSTRUCTIONS

The instrument must be at least partially disassembled to replace the battery, select 3- or 4-wire operation, or for calibration. Troubleshooting or parts replacement may require more complete disassembly. The sequence below describes the basic procedure for disassembling the instrument.

1. Place the instrument face down on a cloth-covered bench or other flat surface.
2. Remove the screws in the back cover of the instrument; carefully pull the back cover off from the top until it is clear and set it aside.
3. At this point, the instrument is sufficiently disassembled to replace the battery, select 3- or 4-wire operation, and perform calibration.
4. For troubleshooting, the shield must be moved aside. Unfold the shield by grasping it at the switch side and carefully pulling it free of the PC board.
5. To remove the PC board, unscrew the standoff securing the board to the front case. The board may now be pulled free, although the wires to the probe jack will still be attached. When the board becomes free of the case, the switch cover will pull free as well. If necessary, the board can be pulled completely free by detaching the wires at the board end. The probe jack may then be removed, if necessary, by removing the nut securing it to the case and pushing the jack free from the inside.

CAUTION

Handle the PC board only at the edges, whenever possible, to avoid possible contamination, which could degrade instrument performance.

6. The LCD assembly may be removed from the PC board by carefully spreading the clips that secure the display to the board. Once the assembly is free of the board, the various parts will be loose, so handle the LCD with care.

CAUTION

Do not touch the elastomer contact strips or mating surfaces on the PC board. Also, use care when spreading the clips to avoid breaking them.

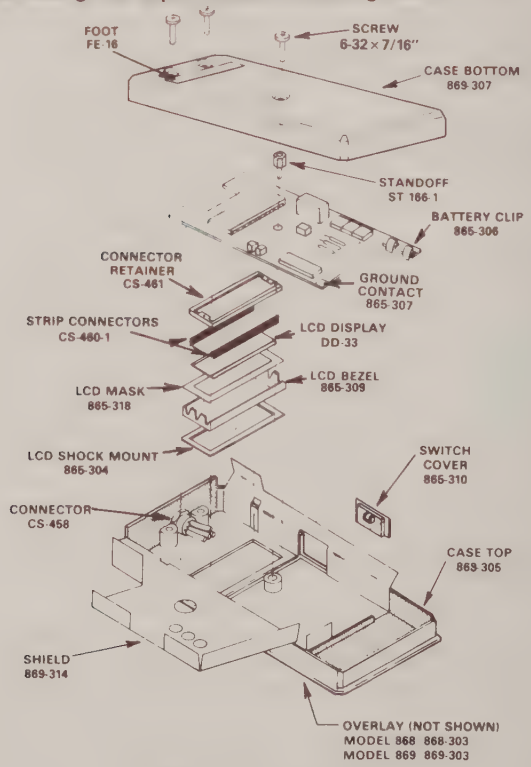


Figure 6. Exploded View

7. The instrument may be reassembled by reversing the above procedure and using Figure 6 as a guide. When assembling the instrument, take special note of the following points:
   A. If the LCD was removed, be sure it is aligned properly on the board with the clips fitted properly into the notch on each side of the board. Also see that the display is properly oriented.
   B. If the probe jack was disconnected, make certain the wires are connected properly. The wire colors are marked on the PC board.
   C. Make sure the PC board is properly secured to the front case with the standoff. The switch cover should be placed on the switch when installing the PC board.
   D. Be sure to install the shield; carefully slide the shield down over the PC board while maintaining proper alignment of the various holes in the shield.
   E. Once the rear cover is in place, secure it with the attachment screws.

THEORY OF OPERATION

This section contains a description of instrument operation during temperature measurements. For the following discussion, refer to the appropriate detailed schematic at the end of this manual or the associated simplified schematic, as required.

4-Wire Signal Conditioning—Two phases are necessary to condition the signal for digitization. Each of these phases has a period of 1/2 the A/D converter back plane (BP) period. These two phases are called the zero phase and the signal phase, respectively. During each phase, appropriate FETs are switched on to configure the circuit as required.

Zero Phase—During the zero phase, certain FETs are switched on to configure the circuit as shown in Figure 7. This configuration leads to the following conditions:

1. C_R is connected in parallel with R_R, causing C_R to charge to a voltage equal to IR_R.
2. C_Z is connected across R_Z, causing C_Z to charge to IR_Z.
3. The input of A_1 is connected to R_T (the temperature probe) and L_4 through L_3. Since negligible current flows into A_1 because of its very high input resistance, the output voltage of amplifier A_1 is equal to $A_1 (IL_4 + V_{OS})$.
4. C_C is connected between the output of A_1 and common. C_C charges to a potential equal to the output of A_1, which is equal to $A_1(IL_4 + V_{OS})$.

5. C_A is connected between the output of A_2 and common. This capacitor charges to a voltage equal to the output of A_1 less the attentuation supplied by A_2, or $A_1A_2(IL_4 + V_{OS})$.

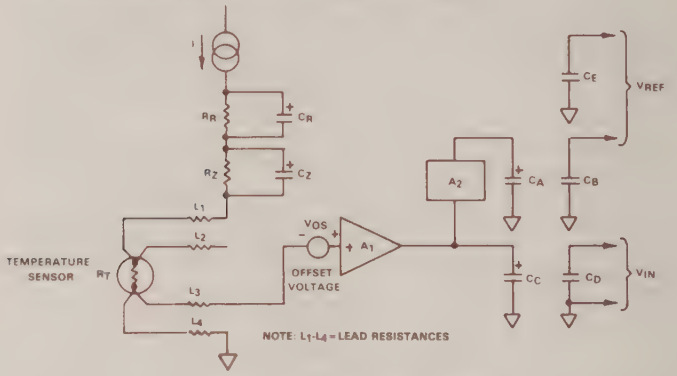


Figure 7. 4-Wire Zero Phase

Signal Phase—During the signal phase, the FET switching configuration changes so that the voltages developed during the zero phase are connected to other parts of the circuit. The configuration during the signal phase is shown in Figure 8. The following discussion assumes that the circuit has gone through more than one charge transformation. During the signal phase:

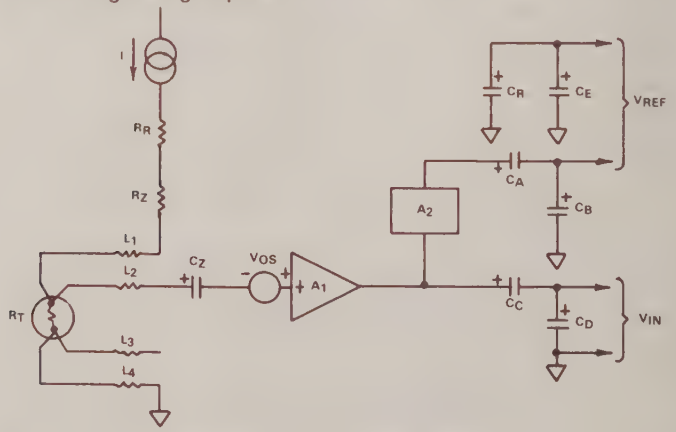


Figure 8. 4-Wire Signal Phase

1. C_R is connected across C_E; after sufficient zero and signal phases have occurred, the charge on C_E approaches the voltage across C_R, which is equal to IR_R.
2. C_Z is connected between L_2 and the input A_1 so the voltage across C_Z opposes the voltage across R_T and L_4. Since C_Z was previously charged to a voltage equal to IR_Z, the output voltage of A_1 during this phase is: $A_1(I(R_T + L_4) - IR_Z + V_{OS})$. Since I is common to both terms, this expression can be simplified to: $A_1(I(R_T\text{-}R_Z + L_4) + V_{OS})$

   Note that R_Z is equal to the value of R_T at 0°C (32°F); R_T has a resistance of 100Ω at that temperature. In this manner, the offset resistance of R_T at 0°C (32°F) is effectively eliminated.
3. C_C is connected between the output of A_1 and the top of C_D; the voltage on C_C opposes the output of A_1, resulting in a value of $A_1(I(R_T\text{-}R_Z + L_4) + V_{OS})\text{-}A_1(IL_4 + V_{OS})$. Simplifying and combining terms, we have: $A_1(I(R_T\text{-}R_Z)$

   Note that this charge transfer process eliminates the effects of lead resistance (L_1, L_2, L_3 and L_4) as well as V_{OS} effects including V_{OS} drift.
4. C_A is connected between the output of the A_2 work and the top of C_B so as to oppose the output voltage of A_2. The voltage across C_B is $A_1A_2(I(R_T\text{-}R_Z + L_4) + V_{OS})\text{-}A_1A_2(IL_4 + V_{OS})$ Simplifying and combining terms, the above expression becomes: $A_1A_2(I(R_T\text{-}R_Z))$. Once again, V_{OS} and lead resistance effects are eliminated.

   During conversion, the voltages developed across C_B, C_D and C_C are digitized by the A/D converter. The basic dual-slope transfer function for the value shown on the 3½ digit display is:

$$\text{Display} = \frac{1000(\text{Vin}_H\text{-Vin}_L)}{\text{Vref}_H\text{-Vref}_L}$$

   Vref_H is equal to the voltage charged on C_E: $\text{Vref}_H = IR_R$

   Vref_L is equal to the voltage charged on C_B: $\text{Vref}_L = A_1A_2(I(R_T\text{-}R_Z))$

   $\text{Vin}_H\text{-Vin}_L$ is equal to the voltage charged on C_D: $\text{Vin}_H\text{-Vin}_L = A_1(I(R_T\text{-}R_Z))$

   The displayed value is then given by the transfer function:

$$\text{Display} = \frac{1000A_1I(R_T\text{-}R_Z)}{IR_R\text{-}A_1A_2I(R_T\text{-}R_Z)}$$

   Simplifying, we have:

$$\text{Display} = \frac{1000A_1(R_T\text{-}R_Z)}{R_R\text{-}A_1A_2(R_T\text{-}R_Z)}$$

   Note that the value of the divider current (I) is NOT critical.

Polarity Detector—The polarity detector decodes the sign signal supplied by the A/D converter by using an EXOR gate (U101D). The output is filtered by R101 and C101 to eliminate unwanted race conditions. This signal controls the state of the MUX gate (U104A) which modifies the A_2 attenuation constant on negative readings for better conformity.

FET Drivers—The FETs control the zero and signal phases of the measurement cycle. These analog switch FETs are controlled by U104B and U104C. An FET is turned on by placing the gate at analog common. Conversely, each FET is turned off by placing the gate at -V potential. U104B is used to drive the FETs necessary for the zero phase, while U104C drives the FETs used for the signal phase.

Low Battery Detector—Low battery detection is accomplished by comparing the regulated voltage between V+ and common to the output of the voltage divider (R107 and R110), which is connected across the battery. When the battery voltage decreases, the output of the voltage divider rises above analog common, causing a comparator (U103A) to change states. This action enables the LO BAT annunciator on the display.

TROUBLESHOOTING GUIDE

The following troubleshooting information is intended for use by qualified personnel who are thoroughly familiar with the proper use of electronic test equipment. Use the schematic, component layout, and parts list at the end of this manual as an aid in identifying components. The theory of operation section may also be helpful in isolating problems.

To gain access to the PC board for troubleshooting, the rear cover and internal shield must be removed, as described in the disassembly instructions. When troubleshooting or replacing components, handle the PC board only by the edges to avoid possible contamination.

Recommended Equipment: DMM with $>1000M\Omega$ input resistance, $\pm 0.05\%$ basic accuracy (Keithley Model 173A or equivalent)
Triggered sweep oscilloscope with DC to 10MHz bandwidth.

Voltage Checks—Several voltage checks can be made simply by connecting a DMM to various A/D converter IC pins. Table 3 summarizes these voltage readings. To make these measurements:

1. Connect the DMM HI terminal to +V (+ terminal of battery).
2. Connect the DMM LO terminal to the indicated point.
3. Measure the DC voltage and compare with the value listed in Table 3.

Table 3. Voltage Checks

Step	Item/Component	Required Condition	Comments
1	Connect DMM HI to +V		Leave connected for all voltage checks.
2	Connect DMM LO to U102, pin 26 (−V)	> 7.2V DC	Battery voltage
3	Connect DMM LO to U102, pin 37 (TEST)	5V ± 1V DC	Digital Common
4	Connect DMM LO to U102, pin 30	≈3V	IN LO (COM)

A/D Converter Checks—A/D converter operation can be checked by measuring the input and reference voltages and then comparing the displayed reading to a value calculated from these input voltages. To check the A/D converter, proceed as follows:

1. Connect a temperature probe to the instrument; make sure the temperature remains stable while making voltage measurements.
2. Connect the DMM LO terminal to analog common (pin 32 of U102).
3. Connect the DMM HI terminal to pin 31 (IN HI) of U102 and record the reading.
4. Connect the DMM HI terminal to pin 30 (IN LO) of U102 and record the reading.
5. Connect the DMM HI terminal to pin 36 (REF HI) of U102 and record the voltage.
6. Connect the DMM HI terminal to pin 35 (REF LO) and record the reading.

Using the measured values above, calculate the displayed reading (neglecting the decimal point) as follows:

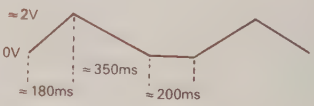
$$\text{Display} = \frac{1000(\text{IN HI}-\text{IN LO})}{(\text{REF HI}-\text{REF LO})}$$

If the displayed value does not agree with the calculated value to within a few digits, the A/D converter is not functioning properly.

Waveform Checks—Several A/D converter waveform checks can be made using an oscilloscope along with the information in Table 4. These checks can be made using the following basic procedure.

1. Connect the oscilloscope LO input to analog common U102, pin 32.
2. Connect the oscilloscope HI input to the A/D converter pin indicated in Table 4.
3. Select an appropriate time base, input attenuator setting, and trigger mode to stabilize the display.
4. Compare the displayed waveform with the corresponding drawing in Table 4.

Table 4. Waveform Checks

Connections	Waveform
Pin 40 to (OSC 1)	
Pin 39 to (OSC 2) Pin 38 same as 39 (OSC 3)	
Pin 27 to (with – full scale input of about 1900 counts (integrator)	
Pin 21 to (Backplane)	

Special Handling of Static-Sensitive Parts—MOS devices are designed to operate at very high impedance levels. As a result, any normal static charge that builds up on your person or clothing may be sufficient to destroy these devices if they are not handled properly. Table 5 lists those parts used in the Models 868 and 869 that might be destroyed by static charge. When handling these devices, use the following precautions:

1. Transport and handle these parts only in containers designed to prevent static build-up. Typically, these parts will be received in static-protected containers of plastic or foam. Keep these devices in their original containers until ready for installation.
2. Remove the devices from their protective containers only at a properly grounded work station. Also ground yourself with a suitable wrist strap.
3. Handle the devices only by the body; do not touch the terminals or pins.
4. Any PC board into which the device is to be installed must also be properly grounded.
5. Use only anti-static type solder suckers.
6. Use only grounded soldering irons.
7. Once the device is installed on the PC board, it is adequately protected, and normal handling may resume.

Table 5. Static Sensitive Parts

Schematic Designation	Keithley Part Number
Q101, Q102, Q105-Q113, Q115, Q116	TG-139
U101	IC-226
U102	LSI-55
U103	IC-325
U104	IC-283

Schematic Desig.	Description	Schematic Location	Keithley Part No.
BA101	Battery, 9V, NEDA 1604	G1	BA-14
C101	Capacitor, 0.1μF, 50V, Ceramic Film	E4	C-237-.1
C102	Capacitor, 0.1μF, 50V, Ceramic Film	G1	C-237-.1
C103	Capacitor, 0.1μF, 50V, Ceramic Film	F1	C-237-.1
C104	Capacitor, 0.1μF, 50V, Ceramic Film	G1	C-237-.1
C105	Capacitor, 0.22μF, 63V, Metalized Polyester	B1	C-344-.22
C106	Capacitor, 0.047μF, 50V, Metalized Polypropylene	E3	C-269-.047
C107	Capacitor, 0.33μF, 63V, Metalized Polyester	E2	C-344-.33
C108	Capacitor, 0.33μF, 63V, Metalized Polyester	F1	C-344-.33
C109	Capacitor, 0.1μF, 63V, Metalized Polyester	D2	C-344-.1
C110	Capacitor, 0.22μF, 63V, Metalized Polyester	D1	C-344-.22
C111	Capacitor, 0.22F, 63V, Metalized Polyester	E3	C-344-.22
C112	Capacitor, 0.1μF, 63V, Metalized Polyester	E2	C-344-.1
C113	Capacitor, 47pF, 500V, Silver Mica or Ceramic	E2	C-320-47pF
C114	Capacitor, 0.22μF, 63V, Metalized Polyester	E1	C-344-.22
C115	Capacitor, 0.22μF, 63V, Metalized Polyester	B2	C-344-.22
CR101	Diode, Silicon 1N4148	B1	RF-28
DS101	Display, LCD	H4	DD-33
J1001	Connector, 4-terminal Connector (mates with J1001)	A3	CS-458 CS-459
J1002	Connector, Battery	G1	C865-306
J1003	Connector, Battery	G1	C865-306
J1004	Connector, Pin	A3	CS-463
J1005	Connector, Pin	A3	CS-463
J1006	Connector, Pin	A4	CS-463
J1007	Connector, Pin	A4	CS-463
P1004	Terminal	A3	CS-462
P1005	Terminal	A3	CS-462
P1006	Terminal	A4	CS-462
P1007	Terminal	A4	CS-462
Q101	JFET, N-Channel	B1	TG-139
Q102	JFET, N-Channel	B2	TG-139

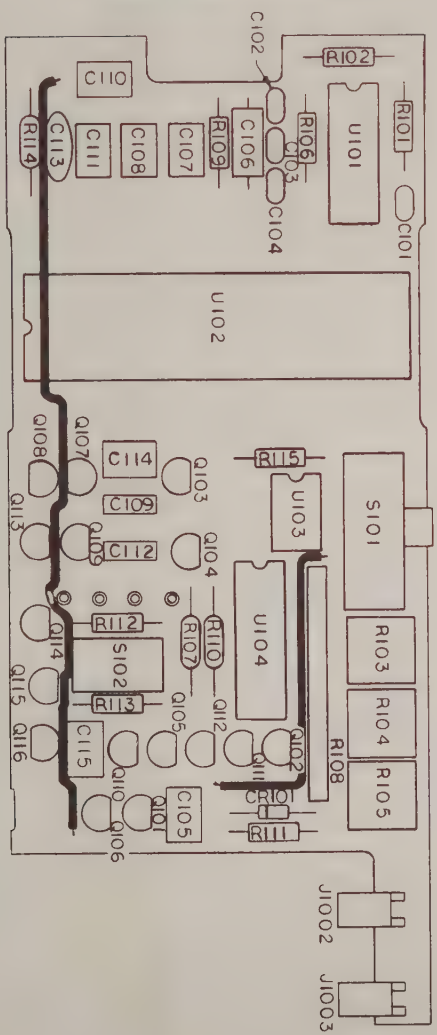
Schematic Desig.	Description	Schematic Location	Keithley Part No.
Q103	Transistor, NPN, Silicon, 2N3904	B4	TG-47
Q104	Transistor, NPN, Silicon, 2N3904	B4	TG-47
Q105	JFET, N-Channel	C3	TG-139
Q106	JFET, N-Channel	C1	TG-139
Q107	JFET, N-Channel	E2	TG-139
Q108	JFET, N-Channel	D2	TG-139
Q109	JFET, N-Channel	E3	TG-139
Q110	JFET, N-Channel	B3	TG-139
Q111	JFET, N-Channel	C2	TG-139
Q112	JFET, N-Channel	C3	TG-139
Q113	JFET, N-Channel	E2	TG-139
Q114	Transistor, NPN, Silicon, 2N3904	B4	TG-47
Q115	JFET, N-Channel	C2	TG-139
Q116	JFET, N-Channel	B2	TG-139
R101	Resistor, 100kΩ, 5%, ¼W, Composition	E4	R-76-100k
R102	Resistor, 470kΩ, 5%, ¼W, Composition	E4	R-76-470k
R103*	Potentiometer, 500Ω	D3	RP-97-500*
R103**	Potentiometer, 1kΩ	D3	RP-97-1k**
R104	Potentiometer, 200Ω	B2	RP-97-200
R105	Potentiometer, 2kΩ	B1	RP-97-2k
R106	Resistor, 470kΩ, 5%, ¼W, Composition	E4	R-76-470k
R107	Resistor, 280kΩ, 1%, 1/8W, Metal Film	D4	R-88-280k
R108*	Resistor, Thick Film	SEV	TF-161*
R108**	Resistor, Thick Film	SEV	TF-159**
R109*	Resistor, 470kΩ, 5%, ¼W, Composition	E2	R-76-470k*
R109**	Resistor, 750kΩ, 5%, ¼W, Composition	E2	R-76-750k**
R110	Resistor, Selected	D4	R-88-†
R111	Resistor, 6.2kΩ, 5%, ¼W, Composition	B1	R-76-6.2k
R112	Resistor, 1MΩ, 5%, ¼W, Composition	A4	R-76-1M
R113	Resistor, 1MΩ, 5%, ¼W, Composition	A3	R-76-1M
R114	Resistor, 392kΩ, 1%, 1/8W, Metal Film	E2	R-88-392k
R115	Resistor, 470kΩ, 5%, ¼W, Composition	G5	R-76-470k

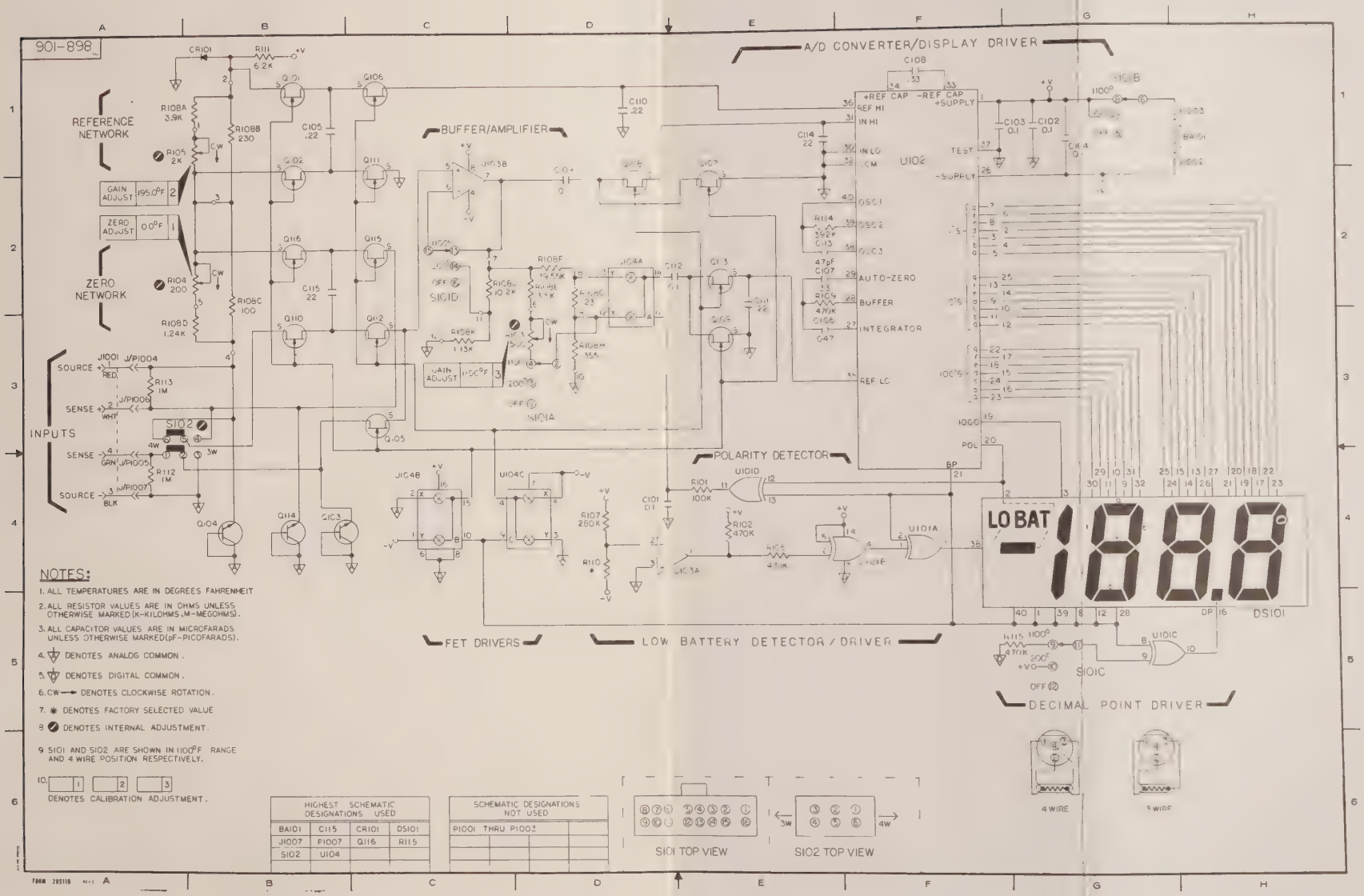
Model 868 and 869 Parts List (Cont.)

Schematic Desig.	Description	Schematic Location	Keithley Part No.
S101	Switch, 4P3T, Slide	SEV	SW-444
S102	Switch, DPDT, Slide	A3	SW-445
U101	IC, CMOS Quad EXOR Gate, 4070	SEV	IC-226
U102	IC, 3½ Digit Low Power A/D Converter ICL7136CPL	F1	LSI-55†
U103	IC, Dual Low Power JFET Op Amp, LF442CN	SEV	IC-325
U104	IC, Triple 2 Channel Multiplexer, 4053	SEV	IC-283

*Model 868
**Model 869
†Part of 865-600

COMPONENT LAYOUT



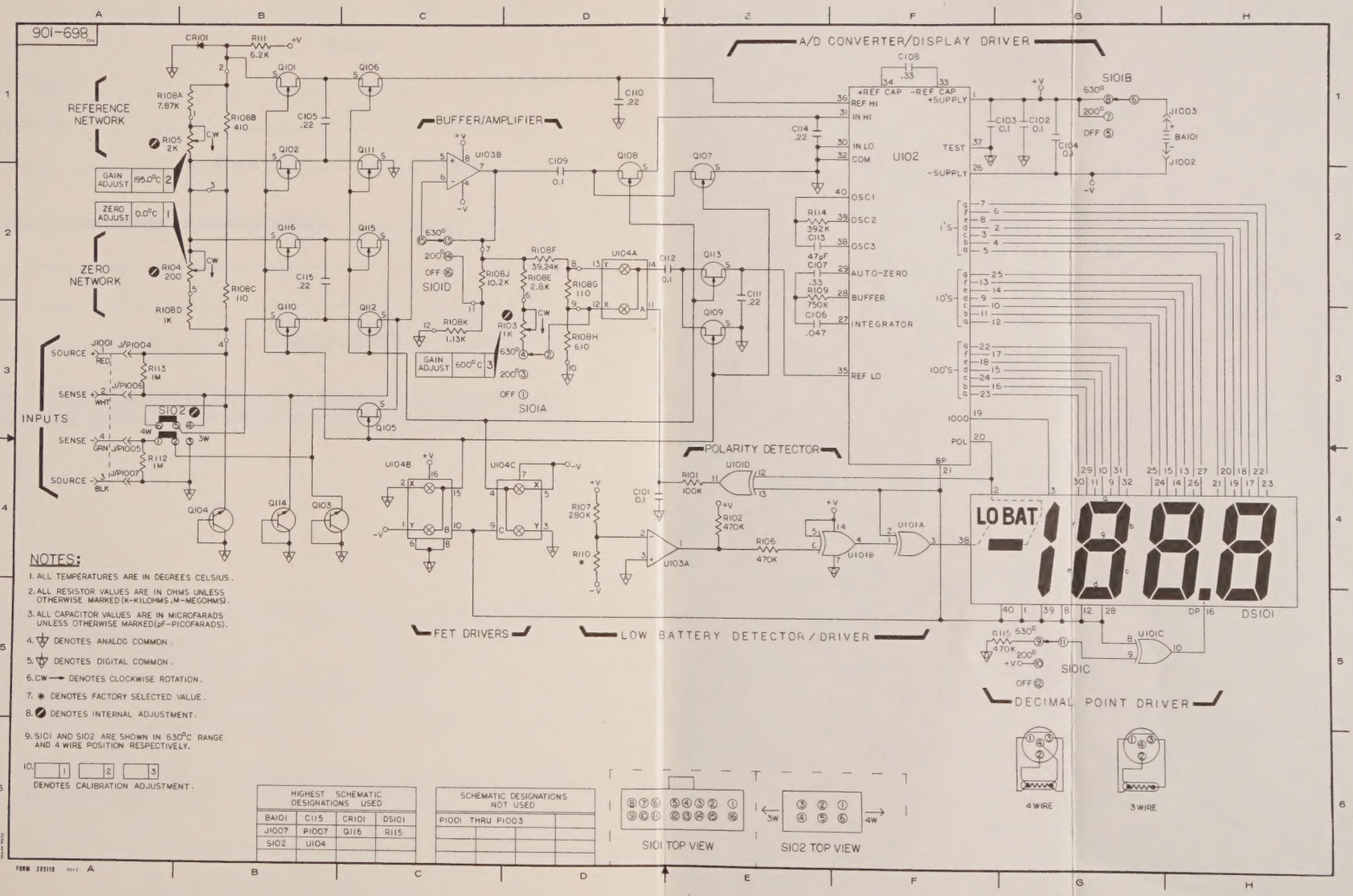


NOTES:

1. ALL TEMPERATURES ARE IN DEGREES FAHRENHEIT
2. ALL RESISTOR VALUES ARE IN OHMS UNLESS OTHERWISE MARKED (K-KILOHMS, M-MEGOHMS).
3. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE MARKED (pF-PICOFARADS).
4. ⏚ DENOTES ANALOG COMMON.
5. ⏚ DENOTES DIGITAL COMMON.
6. CW → DENOTES CLOCKWISE ROTATION.
7. ✱ DENOTES FACTORY SELECTED VALUE
8. ⊘ DENOTES INTERNAL ADJUSTMENT.
9. S101 AND S102 ARE SHOWN IN 1100°F RANGE AND 4 WIRE POSITION RESPECTIVELY.
10. [1] [2] [3] DENOTES CALIBRATION ADJUSTMENT.

HIGHEST SCHEMATIC DESIGNATIONS USED			
BA101	C115	CR101	DS101
J1007	P1007	Q116	R115
S102	U104		

SCHEMATIC DESIGNATIONS NOT USED			
P1001 THRU P1003			


901-698
A/D CONVERTER/DISPLAY DRIVER
REFERENCE NETWORK
ZERO NETWORK
BUFFER/AMPLIFIER
INPUTS
POLARITY DETECTOR
FET DRIVERS
LOW BATTERY DETECTOR/DRIVER
DECIMAL POINT DRIVER
LO BAT
-188.8
DSI01
U102
SIO1A
SIO1B
SIO2
SIOC
SIOD
GAIN ADJUST
ZERO ADJUST
NOTES:
1. ALL TEMPERATURES ARE IN DEGREES CELSIUS.
2. ALL RESISTOR VALUES ARE IN OHMS UNLESS OTHERWISE MARKED (K-KILOHMS, M-MEGOHMS).
3. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE MARKED (pF-PICOFARADS).
4. DENOTES ANALOG COMMON.
5. DENOTES DIGITAL COMMON.
6. CW → DENOTES CLOCKWISE ROTATION.
7. * DENOTES FACTORY SELECTED VALUE.
8. DENOTES INTERNAL ADJUSTMENT.
9. SIO1 AND SIO2 ARE SHOWN IN 630°C RANGE AND 4 WIRE POSITION RESPECTIVELY.
10. DENOTES CALIBRATION ADJUSTMENT.
HIGHEST SCHEMATIC DESIGNATIONS USED
BAI01 C115 CRI01 DSI01
J1007 P1007 Q116 R115
SIO2 U104
SCHEMATIC DESIGNATIONS NOT USED
P1001 THRU P1003
SIO1 TOP VIEW
SIO2 TOP VIEW
4 WIRE
3 WIRE
FORM 285119 REV. A

SERVICE FORM

Model No._____ **Serial No.**_____ **P.O. No.**_____ **Date**_____ **R-**_____

Name _____ **Phone**_____

Company _____

Address_____

City_____ **State**_____ **Zip**_____

List all control settings and describe problem. _____

_____

_____

_____ (Attach additional sheets as necessary.)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)_____

What power line voltage is used?_____ Variation?_____

Frequency?_____ Ambient Temperature?_____°F.

Variation? _____°F. Rel. Humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe below.) _____

_____

_____

Please photo copy this form, and
return it with the instrument.

KEITHLEY

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